Catastrophe Insurance and the Demand for Deductibles

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Introduction: The problem of how best to design a contract of insurance has importance for both the private and public sectors. For the privately owned profit-driven firm, a bad policy design will reduce sales and can therefore be expected to reduce profits. This is problem for the marketing department. If the firm is risk neutral, it will be indifferent among contracts with the same expected loss. The firm will therefore be happy to offer any deductible structure with suitably adjusted premium. The only problem, then, is finding out which deductible structure the customers prefer.

In the public sector the problem is more substantive. Usually insurance contracts are offered by the public sector because there has been some private market failure, and often this is because the private sector has been overwhelmed by the size of the risk. Catastrophe insurance, for example, or major medical insurance, is offered by public agencies because the private sector views these risks as uninsurable. In this case, because of the size of the potential loss, full insurance is simply not an option, even for the public sector. This means that some form of partial insurance using deductibles, co payments, and/or capped loss is the only contract which public agencies can offer.

At this point consumer attitudes to partial insurance take on real importance. It is well known, see Wakker et al (1997), that consumers have a strong aversion to partial insurance, and this being the case, public programs which offer only partial coverage are likely to meet buyer resistance, blunting the effectiveness of the risk transfer which the public policy is designed to achieve. This paper explores this problem in the context of catastrophe insurance.

Optimal Insurance Contract Form. The first economists to consider the question of optimal insurance policy design did so under the hypothesis that the insured agent maximizes expected utility (EU). For example, Arrow (1974) proved that if we stay within the class of contracts with the same expected loss, EU maximizers prefer a contract with full (100%) insurance above a fixed deductible.

Two remarks may be made with respect to this theorem

1) It turns out to be remarkably robust
2) Despite this, it is inconsistent with the evidence on insured's behavior.

With regard to the first point above, it was shown very elegantly by Gollier and Schlesinger (1996) that the optimality of full insurance above some fixed deductible does not require the independence axiom of expected utility maximization. This follows because the probability distribution of “after indemnity” wealth under the “Arrow” contract has the very special shape shown in Fig. 1. For small losses less than the deductible D, the individual bears 100% of the loss. In this region no alternative contract structure can make after indemnity wealth smaller than its value under the Arrow contract of initial wealth minus the insurance premium minus the loss. For losses larger than the deductible, after indemnity wealth has a mass point at wealth minus the premium minus the deductible. Thus any other contract with the same mean must give a wealth distribution which single crosses the Arrow contract probability distribution function from the left.

This property enables Gollier and Schlesinger (op.cit.) to note that the Arrow contract is optimal for all risk averse individuals in the sense of second order stochastic dominance, not just risk averse expected utility maximizers.

This implies that risk averse generalized expected utility maximizers, for example, will also prefer the Arrow contract. In fact, however, the shape of the distribution of wealth function is even more special than this. Any other contract not only has the single crossing property, it has the so called left monotone single crossing property called by Jewitt (1989) “location independent risk”, see also Landsberger and Meilijson(1994). Aversion to left monotone single crossings is the weakest from of risk aversion for which the Arrow contract is optimal. Under commonly made assumptions Rank Dependent Expected Utility (RDEU) (Quiggin (1982) Yaari(1987)) maximizers display this form of risk aversion so that Arrow contracts are also optimal for agents with this type of preference, Vergnaud (1997), see also Chateauneuf , Cohen, and Meilijson (2001).

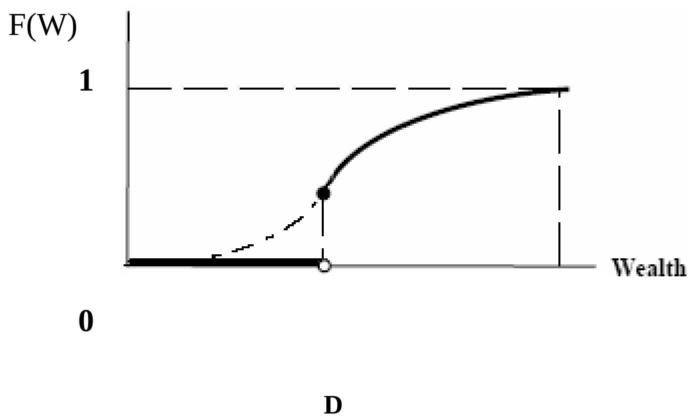

Figure 1

These strong theoretical predictions notwithstanding, however, there is compelling evidence that individuals will simply not buy insurance contracts with high deductibles. The evidence goes back to Pashigian et al (1966). Murray (1972), in a study in which he calibrated each subject's utility function using test lotteries then noted the actual chosen auto deductible, found that of 40 subjects, more than 37 failed to choose deductibles according to the their own calibrated utility function. Moreover, the degree of risk aversion implicit in deductible purchase (around 10) is very high, Dreze (1981)

Again this problem is particularly acute for public providers of catastrophe insurance. Consider the market for earthquake insurance in the State of California. Prior to the Northridge earthquake of 1994, private insurers offered homeowners earthquake coverage with a standard deductible of 10%. After this event, insurers were reluctant to provide earthquake insurance and a State agency, the California Earthquake Authority (CEA), was formed in 1996. Because the CEA entered the earthquake insurance market with such a small quantity of capital (a total claims paying capacity of $7 billion), it was essential that some form of limitation be imposed on the extent of the coverage. The principal way that they did this was to raise the deductible to 15%[1].

[1] The other major method by which the CEA limited its exposure was by only offering a policy which sharply curtailed loss coverage. This is known as the "mini policy". Damage to unattached structures such as garages and swimming pools was excluded, and compensation for damage to contents and

Since its introduction, demand for the CEA policy has plummeted. As yet there is no systematic study of the causes of the fall in demand, but the Consumer's Union and others have blamed it on the high deductible. (Consumer's Union 1999). The CEA itself is aware of the problem as evidenced by their following statement:

" Since the CEA opened its doors in 1996, policyholders and agents have asked the CEA to lower deductibles and raise limits for Contents and Loss of Use" CEA (undated).

Table 1 shows the pattern of earthquake insurance sales relative to residential insurance policies from 1996 to 2002. At the time the CEA was formed just over 30% of Californians purchased earthquake coverage. Today less than 15% do.

Table 1:

Total Residential and Earthquake Insurance Policies in Force in California (1997-2002)
(in millions of policies)

Year	**Residential Policies**	**Earthquake Policies**	**% of Earthquake Policies Sold**
1996	7.60	2.39	31.4
1997	7.89	1.54	19.5
1998	7.86	1.37	17.4
1999	8.12	1.36	16.8
2000	8.16	1.28	15.7
2001	8.12	1.29	15.9.
2002	8.28	1.21	14.6

Obviously a deeper understanding of the role played by deductibles is of some importance.

additional living expenses was capped at very low levels. More recently a policy with expanded coverage and a 10% deductible has been offered.

The Comparative Statics of Insurance Deductibles. The Arrow theorem lays out a general structure for the optimal insurance contract. It does not, however, tell us what the optimal deductible is. For this we need to examine more closely the comparative statics of insurance demand with respect to a change in deductibles. Following Mossin (1968) it is well known that if the insurance premium contains a loading factor, then individuals should choose less than full insurance.

To understand this result and in particular to examine its robustness, it is necessary to lay out a more formal model of insurance demand. We assume the following:

- Risk: We assume a probability of loss (1-q). This implies that the probability of no loss is q.

- Loss: We assume the individual has initial wealth W which is at risk of loss. When there is a loss, we assume its magnitude L is distributed with probability density function f(L) with $0 \le L \le V$. V is the maximum possible loss. We will let $p(\bar{L}) = (1-q)\int_{\bar{L}}^{V} f(L)dL$ so that p represents the unconditional probability that loss exceeds $\bar{L}$.

- Insurance: We assume insurance is available from a risk neutral insurer.

- Deductible: We assume that insurance contracts contain a deductible D. That is, if L<D, the insurer pays out zero, and the insured bears all the loss. If $L \ge D$ the insurer pays out L-D.

- Premium: The premium depends on the chosen level of deductible by the premium function R(D). We assume R is differentiable and that R'(D)<0.

- Loading: We assume a loading factor $\lambda \ge 1$. Thus R(D) = λp(D) (p(D) is the expected loss when deductible = D) When λ=1, insurance will be said to be fair.

This set up deliberately leaves out of account a description of the insured's preferences. We wish to examine the effect of the assumption of different valuation functionals on the deductible demand. We begin by re-examining the standard expected utility (Mossin (1968)) results. To do this we introduce the concept of the Marginal Deductible Gamble.

a) **Deductible demand under the assumption of expected utility maximization.**

The marginal deductible gamble: At a fixed deductible $\overline{D}$, expected utility is given by

$$EU = \int_0^{\overline{D}} U(W - L - R(\overline{D})) f(L) dL + p(\overline{D}) U(W - \overline{D} - R(\overline{D})) \qquad (1)$$

For EU to be maximized at $\overline{D}$, we must have

$$\int_0^{D} U'(W - L - R(D)) - R'(D) f(L) dL + p(D) U'(W - D - R(D))(-1 - R'(D) = 0 \qquad (2)$$

where (2) is evaluated at $\overline{D}$.

Equation (2) can be rewritten as

$$\int_0^{D} U'(W - L - R(D)) \lambda p f(L) dL + p(D) U'(W - D - R(D))(-1 + \lambda p) = 0 \qquad (3)$$

This expression can be given the following interpretation. If we increase the deductible by a small amount dD, it imposes the gamble G = lose \$1 with probability p, lose 0 with probability 1-p. On the other hand it gives the insured the certain gain of the reduction in the premium λp. The marginal gamble question then is this. Will λp be enough to make the insured accept the gamble G?

The answer to this question is made more complex by the fact that the gamble G is to be evaluated at the wealth level (W-$\overline{D}$-R($\overline{D}$)), but the certain gain λp is evaluated at all states of wealth from (W-R($\overline{D}$)) to (W-$\overline{D}$-R($\overline{D}$)). However, things become much simpler when U is concave, i.e. the insured is risk averse. In that case

$$\int_0^{\overline{D}} U'(W - L - R(\overline{D}))\lambda p f(L) dL$$

is certainly less than

$$U'(W - \overline{D} - R(\overline{D}))\lambda p(1-p)\,.$$

Thus if we evaluate the marginal gamble at (W-$\overline{D}$-R($\overline{D}$) we know that the actual value of the reduction in premium cannot exceed λp. We write this as λp^-.

The classic Mossin (1968) results on deductibles can then be found by examining a simple 2 point gamble. We have

Mossin 1. Suppose insurance is fair so that λ =1. Then p^- is clearly not enough to compensate for accepting the gamble G. In that case dD is negative for all D and the individual accepts full insurance.

Mossin 2. Suppose we increase the loading λ. Then the marginal gamble becomes more attractive and for λ large enough dD=0. At this loading $\overline{D}$ is the optimal deductible. To calculate exactly which D is optimal, in general we need to evaluate $\int_0^{D} U'(W - L - R(D))\lambda p f(L) dL$.

Mossin 3. One special case is of some interest. Suppose the individual is at a point of full insurance where D=0. Then it is well known that the individual is locally risk neutral. In that case if λ >1, $\lambda p^- = \lambda p$ and this will certainly be enough to compensate for the expected value (-p) of the gamble lose 0 with probability 1-p lose 1 with probability p. Thus dD>0 and no expected utility maximizer will fully insure at a loading greater than 1. Since most insurance contracts do have a premium loading this result predicts the absence of full insurance in general and is clearly rejected by the evidence.

b) **Deductible Demand under the Assumption of Generalized Expected Utility:** These results generalize immediately if the individual has a valuation functional which is locally expected utility maximizing. This is the case if the individual is a generalized expected utility maximizer as in Machina (1982). There will now be a different local marginal utility function at all wealth levels between (W-L-R(D)) and W(D), but risk aversion guarantees that they are all majorized by the marginal utility at (W-D-R).

c) **Rank Dependent Expected Utility** The situation is quite different, however, if the individual sees distorted probabilities as in the case of RDEU maximization. In this case the distribution of loss function F is replaced by a transformation of itself. Thus let *h* be a bijective, monotone increasing function. Let U be a utility function . Preferences under RDEU are expressed as

$$\text{RDEU} = \int_0^D U(W-L-R)dh(F(L)) + dh(p)U(w-D-R)$$

The property of risk aversion is satisfied if and only if both *U* and *h are* concave (one strictly concave for strict risk aversion).

Now consider what happens at full insurance. The individual remains risk neutral so U is a linear function. But now the gamble G (lose 0 with probability q, lose 1 with probability (1-q)) is distorted by the RDEU weighting function. In particular, the value of (1-q), because it is the bad state, will be increased by the weighting function h. Thus the expected value of the loss exceeds λp for small enough λ even when λ>1. Thus dD will be negative at full insurance and the individual will choose a zero deductible even at an unfair premium.

The argument above does not depend on the insured's level of wealth. Thus if the level of wealth changes, the insured continues to fully insure at small enough loads. This fact has been used by Barniv, Schroath, and Spivak (1999) to argue that the observed pattern of demand for deductibles in flood insurance is explained by the hypothesis that at least some of the insured are RDEU maximizers. As they note, 63% of all insured choose the minimum deductible of \$500 regardless of wealth. For expected utility maximizers this choice would be wealth dependent.

This argument, however, strictly applies only at full insurance. At a deductible of \$500 RDEU maximizers would also change the deductible in response to a change in wealth, so the observed zero wealth elasticity seems as much a problem for RDEU as it would be for differentiable valuation functionals. It would seem that if the demand for low deductibles is to be explained by RDEU maximization, we need more information regarding the nature of the g function and the value of the loading.

d) **Regret Theory:** One final attempt to explain behavior with respect to deductibles in probability terms drops the requirement that the marginal valuation field be integrable. When it is not, preferences may still be well defined, but we need more than one marginal valuation to define them. One well known bi-marginal preference theory is the theory of regret, Loomes and Sugden (1982), Bell (1982). Valuations which depend anti-symmetrically on two marginal movements are known as two forms, and recently Braun and Muermann (2004) (BM) have modeled the insurance purchase decision in such terms.

The regret based valuation function which they propose is

$$V(W) = EU(W) - kg(EU(W^{MAX}) - EU(W))$$

They call this approach Regret Theoretical Expected Utility (RTEU). Here $k \geq 0$. If $k=0$ then the individual is clearly an expected utility maximizer. The function g satisfies $g' > 0$, $g'' < 0$ $g(0) = 0$, and $EU(W^{MAX})$ is the expected utility of an individual who knows in advance which states will occur and who therefore will not buy insurance in those states in which the payoff falls short of the premium.

In marginal terms the individual in the BM model contemplating a small increase in the level of deductible must evaluate two marginal gambles. The first gamble evaluates $\frac{dEU}{dD}$ and this is exactly the gamble G which we have already discussed. The second gamble is $kg'()\left[\frac{dEU(W^{MAX})}{dD}-\frac{dEU}{dD}\right]$. Clearly the addition of this second gamble will change the insured's behavior with respect to deductibles.

As BM show, their Proposition 7, this new gamble changes Mossin's theorem. As before, at full insurance the individual is risk neutral so $\frac{dEU}{dD}$=0. On the other hand, at full insurance the term $kg'()\left[\frac{dEU(W^{MAX})}{dD}-\frac{dEU}{dD}\right]=kg'()\left[\frac{dEU(W^{MAX})}{dD}\right]$ must be negative. An increase in deductible by the small amount dD is still equivalent to the gamble G = {-1 with probability p(0), 0 with probability (1-p(0))} but now, since the individual will not pay the premium in those states in which no loss occurs, even if the premium is fair, it will not fully compensate the individual for taking on the gamble. Since EU(W^{MAX}) is reduced, $\frac{dV}{dD}$>0 and so an RTEU individual will choose a positive deductible even at fair odds.

This result goes against the evidence that individuals prefer smaller deductibles than is predicted by smooth integrable valuation functions, but it only holds when premiums are fair. When premiums are unfair, BM show that the situation is a little more delicate, BM Proposition 9. The easiest case is to consider is again the case of full insurance. Since the probability of no accident is q, and the RTEU maximizer is risk neutral, they will choose a deductible for all loadings λ satisfying $\lambda \le \frac{1}{1-q}$ i.e. all loadings small enough. Once the loading becomes large enough to compensate the individual for the fact the premium (though fair) is not saved in those states in which loss no occurs, i.e. is saved only with probability (1-q), then $kg'()\left[\frac{dEU(W^{MAX})}{dD}\right]$ will become positive and thus $\frac{dV}{dD}$ will become negative. This result, as BM show, in fact holds at all levels of deductible so that at high enough loadings, the RTEU maximizer chooses a smaller deductible than the EU maximizer whereas at low loadings the deductible is higher As with the RDEU model, however, it is not clear that this explains the demand for low deductibles. As Barniv et al (op.cit.) note, flood insurance for example has a very low loading and in this case RTEU maximization drives the demand for deductibles in precisely the wrong direction. It is an empirical question whether loadings are large enough to allow regret theory to explain the high demand for deductibles and it is also an open question whether or not the Arrow theorem holds in this case.

Context Models of Choice of Deductible: Both the RDEU and the RTEU models of insurance demand are firmly within the framework of post 1950s models of choice. That is, they both take as the "manifold of choice" a set of gambles, and they both define preferences as a field of marginal valuations on this manifold. That they make opposite predictions about behavior points to the fact that as we move away from the assumption that gambles are evaluated by a smooth integrable functional (whether satisfying the independence axiom or not), the range of explainable behavior expands until virtually anything goes.

Moreover, if the choice set is a set of gambles, the independence axiom is eminently reasonable. Would anyone presented with a clear violation of this axiom behave differently from Jimmie Savage and not request that they be allowed to change their mind? Given this, it becomes reasonable to ask whether it makes sense to frame the insurance deductible choice question as a choice over gambles at all. For the gambling frame to be appropriate, individuals must be able to translate the insurance problem into a gambling choice, have a well defined set of preferences over gambles and have an estimate of the probability of loss and the loadings on the contract. If any of this is missing, some other frame may be appropriate.

But what other frame? That is to say, what do individuals think they are doing when they choose deductible A over deductible B? One obvious but still very controversial method for answering this question is to ask them. Murray (op.cit.) did just this, and though the sample is small (just 40 subjects) the answers are worth repeating, because, as noted, virtually none of the respondents gave answers which could even remotely be translated into a preference field over gambles.
He states

> “There are a few interesting trends which begin to appear in the reasons stated by the subjects for purchasing their level of deductible. For those choosing a $50 deductible, two said that it was picked by their parents. Each of three persons said “It was the smallest possible”, “It gave general protection” and “ It was the best deal.” One interesting response was that “Any accident I have will be less than $200 since I am a careful driver.”
>
> For those with a $100 deductible, three said that their agent chose it and one said that the bank picked it. This supports the author’s perception that agents tend to recommend the $100 deductible to most of their clients. The most commonly given response (8) was that this was cheaper. (It would seem that if this were the motivating factor the individual would buy an even larger deductible, since that would be cheaper yet.) One reason for saying that the $100 was cheaper appeared when the subject was asked to list the alternative deductibles available. In more than 90 per cent of the answers, only $50 and $ 100 were listed as alternatives. The buyer simply is not aware that other alternatives exist. Other responses were: “Could always squeeze out $100” (Two people gave this response which comes closest to coinciding with a utility analysis) “Makes for fewer claims and that’s better” and “Never had any accidents where I had to pay.”

All of this suggests that it may be useful to develop models of deductible choice which begin from a different point of view. Of course, in describing other factors which may influence this behavior, there is no reason why one single model should fit all actors. Some buyers may be RDEU maximizers, some may be RTEU maximizers (indeed some may even be EU maximizers.) Loomes and Segal (1994) further develop this point of view.

For choice problems which resemble the choice of deductible from a menu of deductibles, there is evidence that individuals do not approach the decision with hard wired preferences at all. Instead their preferences and therefore their choices are determined by the set of choices offered. This choice theory, called the context theory of choice, has shown remarkable success at predicting choices in situations, such as deductible choice, where the choice is made infrequently and with minimal information.

It has become a standard part of the literature on marketing, see, Simonson and Tversky (1992), Tversky and Simonson(1993), and Simonson (1993).
In the case of insurance deductible choice, the context theory would argue that many individuals choose the deductible simply by choosing the lowest deductible or possibly the second lowest deductible (to avoid extremes). The evidence that individuals do have such a propensity is very strong. In every empirical study with which we are familiar, encompassing different line of insurance and different premium structures, the majority of the agents chose either the lowest deductible or the second lowest deductible, See Table 1.

Table 1: Fraction of Participants Choosing the Smallest Deductibles:

AUTHOR(S) OF STUDY	TYPE	VALUE OF SMALLEST DEDUCTIBLE	FRACTION CHOOSING LOWEST DEDUCTIBLE %	VALUE OF SECOND SMALLEST DEDUCTIBLE	FRACTION CHOOSING SECOND LOWEST DEDUCTIBLE %
Pashigian et al (op.cit.)	Auto	$50	58	$100	46
Murray (op.cit.)	Auto	$50	30	$100	60
Barniv et al (op.cit.)	Flood	$500	63	$1000	22.7
eHealthinsurance: http://images.ehealthinsurance.com/ehealthinsurance/expertcenter/UITxCreditFactSheet.pdf	Health	$500	40.5 (26% of families)	$1000	22 (24% of families)

As far as we know there are as yet no laboratory tests of context models of insurance deductible choice, but following the Tversky/Simonson methodology one is easy to design. Suppose we present subjects with a menu of deductibles and premia and observe their choices. Now expand the menu by adding a new deductible which is smaller than any in the original set. All preference based theories of choice predict that the only switching which will take place is switching into the lowest deductible class. Switching into what is now the second lowest deductible class is evidence of context dependent preferences.

Context models of choice are reasonably straightforward to test if insureds are presented with a menu of deductibles. There is more difficulty when only one deductible is offered. For example, the original C.E.A. earthquake contract had a single deductible of 15%. Based on market research the reluctance of homeowners to buy this contract was widely attributed to this deductible being too high. What is less clear is why homeowners would think this way. By law the contract premium was required to be actuarially fair, and given a small administrative loading, this structure would seem to be Arrow ideal.

Some commentators believe that homeowners calculate that if they are at risk for say a $200,000 loss with a 15% deductible they will have paid $30,000 in premia before they could recover a penny. Whatever the reasoning, the introduction of a new contract with a 10% deductible has hardly been a success. Only 15% of homeowners in California now purchase earthquake insurance, (down from 30% in 1996) and of those who do buy this insurance only 1/5 choose the 10% deductible, 4/5 remaining with the original 15%. Currently there is pressure to introduce a 5% deductible and it will be interesting to see if this makes the product any more attractive.

Implications for High Cost Insurance Contract Design: The finding that individuals generally prefer low deductibles has clear implications for the design of high cost insurance contracts. The CEA experience suggests that the Arrow solution is not viable. With this in mind, the structure recently adopted in the USA for prescription drug coverage for retirees seems not so bizarre. A low deductible for small losses seems necessary to induce individuals to participate in the program at all. A large deductible in the middle range is necessary to control the outgoings. Finally a low deductible is necessary at the high end to prevent the bankruptcy of very sick seniors. Viewed this way it is not clear that politicians had many alternatives to the chosen plan.

Conclusion: In the private sector marketers of insurance must choose contract structures which their customers will buy. The customer, right or wrong, is always right. In the public sector, however, matters are not so simple. There is now serious debate as to whether or not politicians should offer citizens only rational preference based solutions or should go along with behavioral choices perhaps in the interests of being re-elected, see Camerer et al (2003). Based on the ideas of Thaler and Sunstein (2003) one way out of this dilemma would be make the Arrow contract (high deductible) the default option and allow free choice over other schemes, see also Choi et al (2003). It remains to be seen whether or not in this case the stasis of the default option would overcome the context driven push towards the lowest possible deductible

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